

GRASS CHANNEL/VEGETATIVE SWALES

Description

The term "swale" (a.k.a., grassed channel, dry swale, wet swale, biofilter) refers to a series of vegetated, open channel practices that are designed specifically to treat and attenuate stormwater runoff for a specified water quality volume. As stormwater runoff flows through the channels, it is treated through filtering by the vegetation in the channel, filtering through a subsoil matrix, and/or infiltration into the underlying soils. There are many design variations of the grassed swale, including the grassed channel, dry swale and wet swale. The specific design features and treatment methods differ in each design, but all are improvements on the traditional drainage ditch. Each incorporate modified geometry and other design features to use the swale to treat and convey stormwater runoff. Communities should consult the South Carolina Department of Transportation prior to permitting vegetative swales to determine applicability to State of South Carolina Road Construction standards.

Applicability

Grassed swales can be applied in most development situations with few restrictions. Swales are well-suited to treat highway or residential road runoff because their linear nature.

Regional Applicability

Grassed swales can be applied in most regions of the country. In arid and semi-arid climates, however, the value of swales needs to be balanced against the water needed to irrigate them.

Ultra Urban Areas

Ultra urban areas are densely developed urban areas in which little pervious surface exists. Grassed swales are generally not well suited to ultra urban areas because most runoff is conveyed in underground storm drain pipes rather than open channels on the surface.

Stormwater Hotspots

Stormwater hotspots are areas where land use or activities that generate highly contaminated runoff, with pollutant concentrations that exceed of those typically found in stormwater. A typical example is a gas station or convenience store. With the exception of the dry swale design (*see Design Variations*), hotspot runoff should not be directed toward grassed channels. Swales infiltrate stormwater and can intersect the watertable, thereby increasing the risk that hotspot runoff will become a threat to groundwater quality.

Stormwater Retrofit

A stormwater retrofit is a stormwater treatment practice installed after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. One common retrofit

opportunity is to use grassed swales to replace existing drainage ditches. Ditches are traditionally designed only to convey stormwater away from roads. In some cases, it may be possible to incorporate features to enhance their pollutant removal or infiltration using check dams (i.e., small dams along the ditch that trap sediment, slow runoff, and reduce the longitudinal slope). Since individual grassed swales cannot treat a large drainage area, it may be expensive to retrofit an entire watershed because of the large number of practices required to treat an entire watershed. Still, they are often an attractive retrofit option for a single site.

Cold Water (Trout) Streams

Grassed channels are a good treatment practice for watersheds that have cold water streams. Swales do not pond water for a long period of time, and often induce infiltration. As a result, standing water will not typically be subjected to warming by the sun in these practice.

Siting and Design Considerations

Designers need to consider conditions at the site level before installing grass swales. In particular, they need to incorporate design features that improve the longevity and performance of the swale, and minimize its maintenance burden.

Siting Considerations

Designers always need to ensure that grass channels are feasible and appropriate at the site in question. Depending on the design variation, grassed channels can be restricted at some sites.

Drainage Area

Individual grassed channels should generally treat small drainage areas (i.e., less than five acres). If grass channels are used to treat larger areas, the stormwater flow velocity through the practice becomes too great to treat runoff or prevent erosion in the channel.

Slope

Grassed swales should be used on sites with relatively flat slopes (i.e., less than 4% slope). Runoff velocities within channels often become too fast on steeper slopes, which can cause erosion, and prevent adequate infiltration or filtering in the channel.

Soils /Topography

Grassed channels can be used on most soils with the exception of highly impermeable soils. In the Dry Swale (see *Design Variations*) a fabricated soil bed replaces on-site soils, in order to ensure that runoff is filtered as it travels through the soils of the channel.

Groundwater

Restrictions on the depth to groundwater depend on the type of channel used. In the Dry Swale and Grassed Channel options, designers should separate the bottom of the swale from the groundwater by at least two feet to prevent a moist swale bottom, or groundwater contamination. In the Wet Swale option it is permissive to intersect the watertable since treatment is enhanced by a wet pool.

Design Considerations

Although there are different design variations of the grassed channel (see *Design Variations*), several design considerations are common to all (for more information see Manual Builder Category). For example, the cross-sectional geometry of all three options is similar. Channels should generally have a trapezoidal or parabolic cross section with relatively flat side slopes (generally flatter than 3:1). Designing the channel with flat side slopes also maximizes the wetted perimeter. The wetted perimeter is the length along the edge of the channel cross section where runoff flowing through the channel is in contact with the vegetated sides and bottom of the swale. Increasing the wetted perimeter slows runoff velocities and provides more contact with vegetation to encourage filtering and infiltration. Another advantage of flat side slopes is that runoff entering the grassed swale from the side receives some pretreatment along the side slope. The flat channel of all three design options should be between two and eight feet wide. The minimum width ensures a minimum filtering surface for water quality treatment, and the maximum width prevents braiding, the formation of small channels within the swale bottom.

Another similarity among all three designs is the type of pretreatment needed. In each option, a small forebay should be used upstream of the channel to trap incoming sediments. A pea gravel diaphragm (a small trench filled with river run gravel) can also be used to pretreat runoff that enters the sides of the channel.

Two other design features that enhance the treatment ability of grassed channels are a flat longitudinal slope (generally between 1% and 2%) and a dense vegetative cover in the channel. The flat slope helps to reduce the velocity of flow in the channel. The dense vegetation also helps reduce flow velocities, protects the channel from erosion, and acts as a filter to treat stormwater runoff. During construction, it is important to stabilize the channel before the turf has been established, either with a temporary grass cover, or the use of natural or synthetic erosion control products.

In addition to treating runoff for water quality, grassed swales need to convey larger storms safely. Typical designs allow the runoff from the 2-year storm (i.e., the storm that occurs, on average, once every two years) to flow through the swale without causing erosion. Swales should also have the capacity to pass larger storms (typically a 10-year storm) safely.

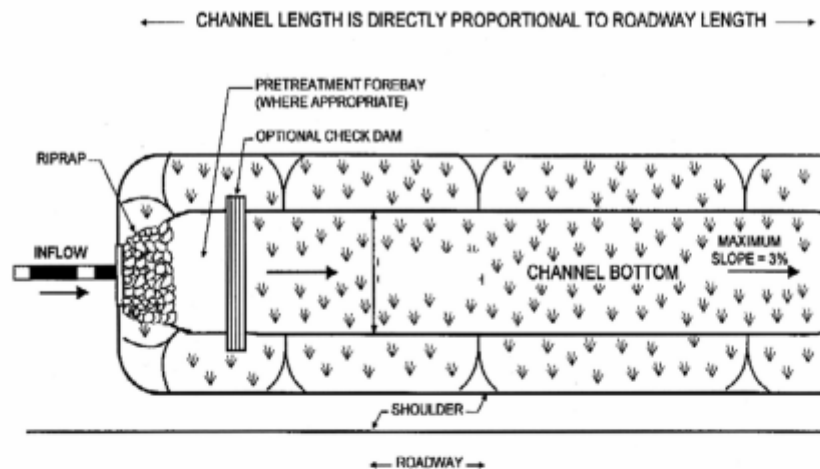
Design Variations

The following discussion identifies three different variations of open channel practices, including the grassed channel, the dry swale, and the wet swale.

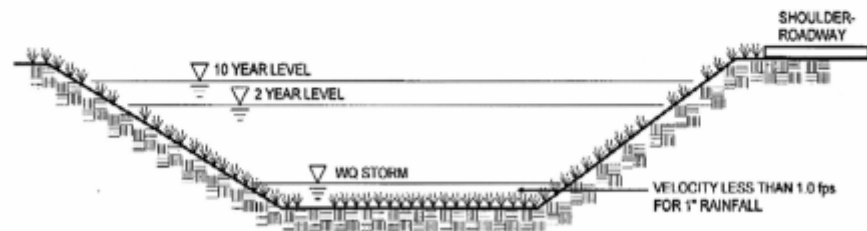
Grassed Channel

Grass channels are the most similar to a conventional drainage ditch, with the major differences being flatter side slopes and longitudinal slopes, and a slower design velocity for water quality treatment of small storm events. Grass channels are the least expensive option, but also provide the least reliable pollutant removal. The best application of a grassed channel is as pretreatment to other structural stormwater treatment practices.

A major difference between the grassed channel and other stormwater treatment practices is the method used to size the practice. Most stormwater treatment practices are sized by volume of runoff. That is, the practice captures and treats a defined water quality volume, or the volume of water. The grassed channel, on the other hand, is based on flow rate (i.e., a peak flow from the water quality storm; this varies from region to region but a typical value is the one inch storm), grass channels should be designed to ensure that runoff takes, an average of, ten minutes to flow from the top to the bottom of the channel. A procedure for this design can be found in *Design of Stormwater Filtering Systems* (CWP, 1996).



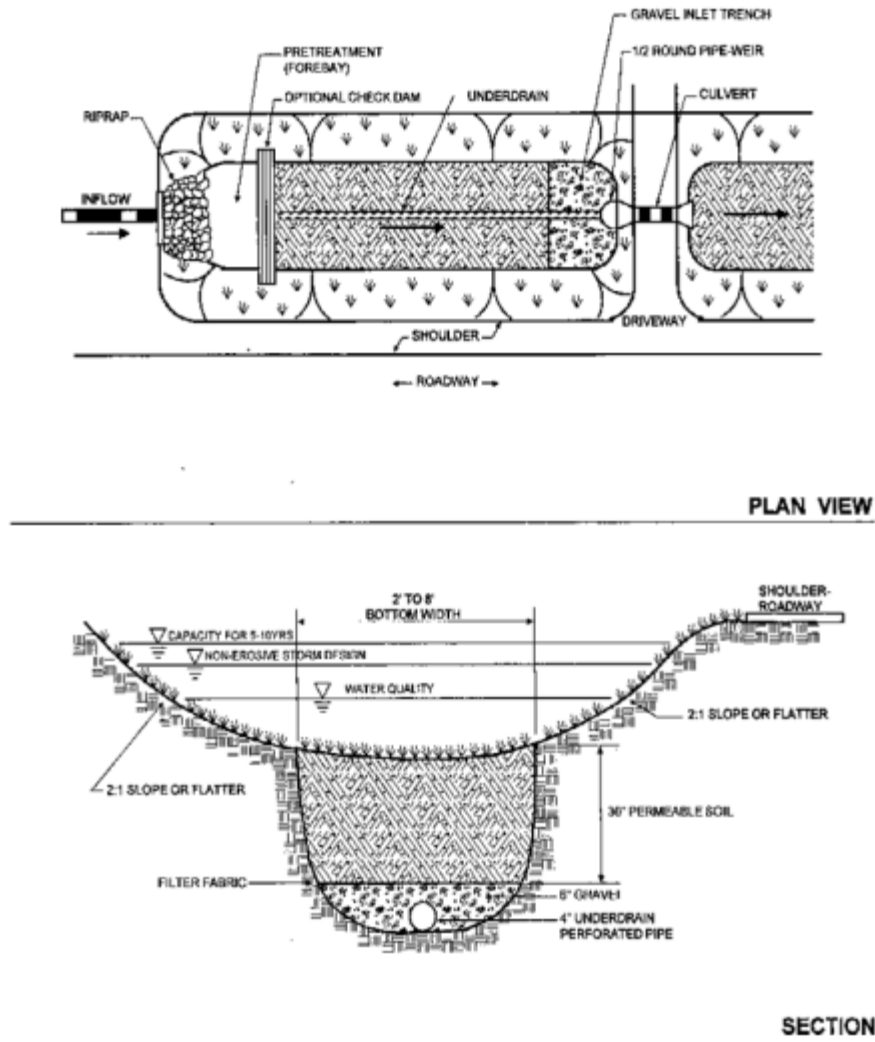
PLAN VIEW



SECTION

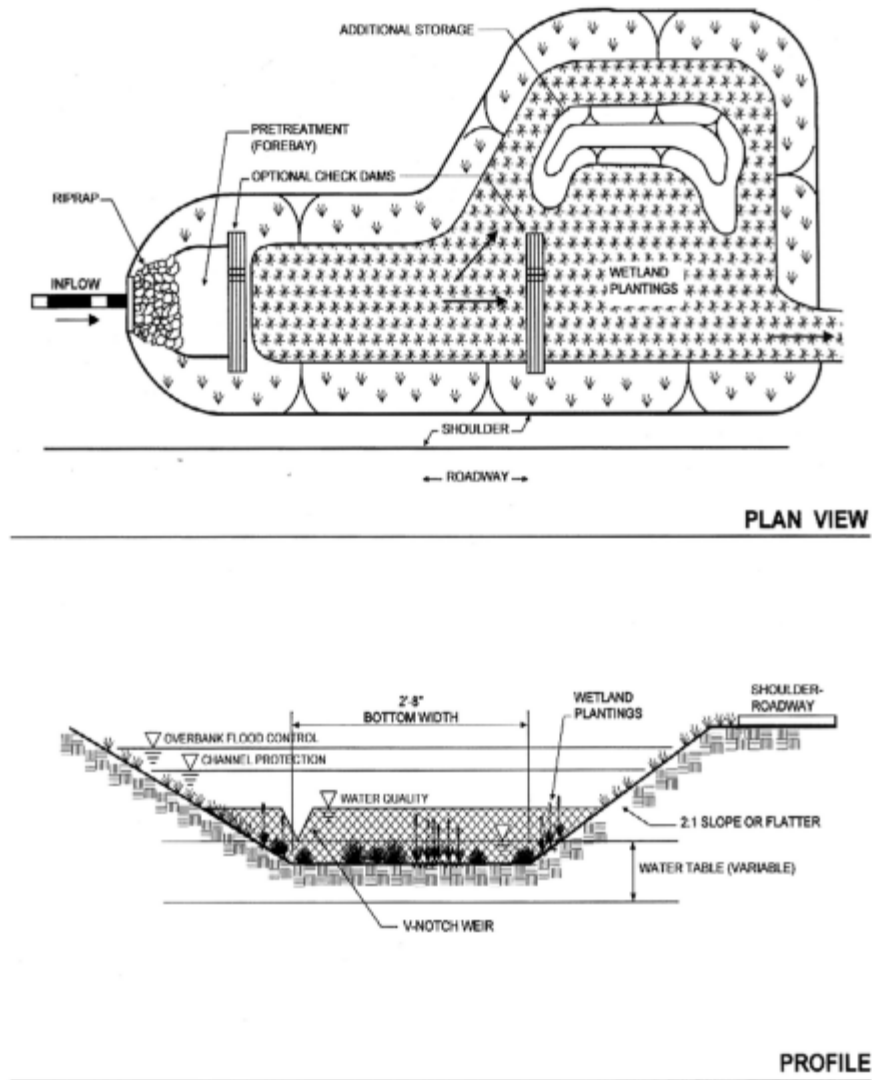
Dry Swales

Dry swales are similar in design to bioretention areas (see the [Bioretention Fact Sheet](#)). These designs incorporate a fabricated soil bed into the bottom of the channel. Existing soils are replaced with a sand/soil mix that meets minimum permeability requirements. An underdrain system is also installed under the soil bed. Typically, the underdrain system is created by a gravel layer which encases a perforated pipe. Stormwater treated by the soil bed flows into the underdrain, which conveys treated stormwater back to the storm drain system (see Figure 1).



Wet Swales

Wet swales intersect the groundwater, and behave almost like a linear wetland cell (see [Stormwater Wetland Fact Sheet](#) for more information). This design variation incorporates a shallow permanent pool and wetland vegetation to provide stormwater treatment (see Figure 2). One disadvantage to the wet swale is that it cannot be used in residential settings because the shallow standing water in the swale is often viewed as a potential nuisance by homeowners.



Regional Variations

Arid Climates

In semi-arid climates, grass channels should be designed with drought-tolerant vegetation, such as buffalo grass. The value of grass channels in arid climates is questionable, given the cost and volume of irrigation water needed to sustain the system.

Limitations

Grassed channels have some limitations, including:

- Individual grass channels cannot treat a very large drainage area.

- Grass channels do not appear to be effective at reducing bacteria levels in stormwater runoff.
- Wet swales may become a nuisance due to mosquito breeding.
- If designed improperly (e.g., proper slope is not achieved), grassed channels will have very little pollutant removal.
- A thick vegetative cover is needed for proper function.

Maintenance Considerations

Maintenance of grassed channels mostly involves maintenance of the grass or wetland plant cover. Typical maintenance activities are included in Table 1.

Typical Maintenance Activities for Grassed Swales (Source: Adapted from CWP, 1996)	
Activity	Schedule
<ul style="list-style-type: none">• Inspect pea gravel diaphragm for clogging and correct the problem.• Inspect grass along side slopes for erosion and formation of rills or gullies and correct.• Remove trash and debris accumulated in the inflow forebay.• Inspect and correct erosion problems in the sand/soil bed of dry swales.• Based on inspection, plant an alternative grass species if the original grass cover has not been successfully established.• Replant wetland species (for wet swale) if not sufficiently established.	Annual (Semi-annual the first year)
<ul style="list-style-type: none">• Rototill or cultivate the surface of the sand/soil bed of dry swales if the swale does not draw down within 48 hours.• Remove sediment build-up within the bottom of the swale once it has accumulated to 25% of the original design volume.	As needed (Infrequent)
<ul style="list-style-type: none">• Mow grass to maintain a height of three to four inches	As needed (frequent seasonally)

Effectiveness

Structural stormwater treatment practices can be used to achieve four broad water resource protection goals. These include: *Flood Control*, *Channel Protection*, *Groundwater Recharge*, and *Pollutant Removal* (see Manual Builder Category for more information). In general, grassed swales can be used to meet groundwater recharge and pollutant removal goals.

Groundwater Recharge

Grassed channels and dry swales provide some groundwater recharge if a high degree of infiltration is achieved by the practice. Wet swales, however, generally do not contribute to groundwater recharge, as infiltration is impeded by the accumulation of organic debris on the bottom of the swale.

Pollutant Removal

Few studies are available regarding the effectiveness of grassed channels. In fact, only nine studies have been conducted on water quality swales. The data suggest relatively high removal rates for some pollutants, but negative removals for some bacteria, and modest removal capability for phosphorous. Table 2 provides pollutant removal data derived from CWP's National Pollutant Removal Database for Stormwater Treatment Practices:

Table 2. Pollutant Removal of Water Quality Swales (Winer, 2000)	
Pollutant	Pollutant Removal (%)
TSS	81±14 ¹
TP	34±33
NOx	31±49
Metals	42 - 71
Bacteria	-25 ²
1:± values represent 1 standard deviation	
2: Data based on fewer than five data points	

While it is difficult to distinguish between different designs based on the small amount of available data, grassed channels generally have poorer removal rates than wet and dry swales, although wet swales appear to export soluble phosphorous (Harper, 1988; Koon, 1995). It is not clear why swales export bacteria. One explanation is that bacteria thrive in the warm swale soils. Another is that studies have not accounted for some sources of bacteria, such as local residents walking dogs within the grassed swale.

Cost Considerations

There is little data available to estimate the difference in cost between various swale designs. One study (SWRPC, 1991) estimated the construction cost of grassed channels at approximately 25¢ per square foot. This does not include the design costs, or contingencies. Brown and Schueler (1997) estimate these

costs at approximately 32% of construction costs for most stormwater management practices. For swales, however, these costs would probably be significantly higher since the construction costs are so low compared with other practices. A more realistic estimate would be a total cost of approximately 50¢ per square foot, which compares favorably with other stormwater management practices.

The cost of dry swales may be estimated to be approximately 80% of bioretention systems, or approximately \$5.50 per cubic foot of storage (see Bioretention Fact Sheet). This assumption is based on the similarity of design between dry swales and bioretention.

References

Brown, W. and T. Schueler. 1997. The Economics of Stormwater BMPs in the Mid-Atlantic Region. Prepared for: Chesapeake Research Consortium. Edgewater, MD. Center for Watershed Protection. Ellicott City, MD.

Center for Watershed Protection (CWP). 1996. Design of Stormwater Filtering Systems. Prepared for: Chesapeake Research Consortium. Solomons, MD. and US EPA Region V. Chicago, IL.

Center for Watershed Protection (CWP), Environmental Quality Resources and Loiederman Associates. 1997. Maryland Stormwater Design Manual. Prepared for: Maryland Department of the Environment. Baltimore, MD.

Harper, H. 1988. Effects of Stormwater Management Systems on Groundwater Quality. Final Report. Environmental Research and Design, Inc. Prepared for Florida Department of Environmental Regulation. Tallahassee, FL.

Koon, J. 1995. Evaluation of Water Quality Ponds and Swales in the Issaquah/East Lake Sammamish Basins. King County Surface Water Management and Washington Department of Ecology. Seattle, WA 75 pp.

Reeves, E. 2000. Performance and Condition of Biofilters in the Pacific Northwest, Article 112 in The Practice of Watershed Protection. Center for Watershed Protection. Ellicott City, MD.

Schueler, T. 2000. Comparative Pollutant Removal Capability of Urban Stormwater Treatment Practices: A Reanalysis, Article 64 in The Practice of Watershed Protection. Ellicott City, MD.

Seattle Metro and Washington Department of Ecology. 1992. Biofiltration Swale Performance. Recommendations, and Design Considerations. Publication No. 657. Olympia, WA

Southeastern Wisconsin Regional Planning Commission (SWRPC). 1991. Costs of Urban Nonpoint Source Water Pollution Control Measures. Wackesha, WI.

US EPA. 1993. Office of Water. Guidance to Specify Management Measures for Sources of Nonpoint Pollution in Coastal Waters. EPA-840-B-92-002. Washington, DC.

Watershed Management Institute (WMI). 1997. Operation, Maintenance, and Management of Stormwater Management Systems. Prepared for: US EPA Office of Water. Washington, DC

Winer, R. 2000. National Pollutant Removal Database for Stormwater Treatment Practices: 2nd Edition. Center for Watershed Protection. Ellicott City, MD.